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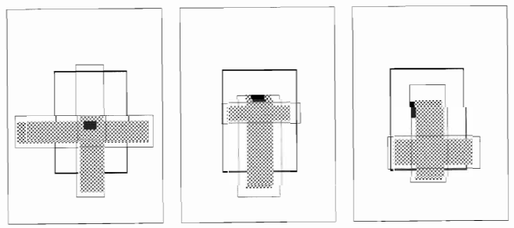

Incorporating Guidelines Into A Case-Based Architectural Design Tool

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This paper discusses an ongoing project called Archie, a collaboration between cognitive scientists and researchers in artificial intelligence and architecture, aimed at creating computer-based aids for conceptual design. Archie is a "case-based design aid" (CBDA): a tool that provides designers flexible access to evaluated examples of past experience that they can use in their own designs. Archie is a "clever" hypermedia database aimed at aiding conceptual design in architecture. It contains about 200 problems, responses, stories, and building descriptions derived from evaluations of six libraries and two courthouses.

In this paper we provide a brief history and description of Archie and discuss some issues that have come into focus through developing and initially evaluating the system: how specific architectural case information can be organized; how users can be provided more general information about issues and building types; and how information can be indexed. In each of these we briefly discuss the current state of the system and propose some potential future directions.

Introduction

Architectural design is exceedingly complex and sometimes messy. Designers may start with only a general view of the problem to be solved; an important part of the design process is often to *create* the problem as well as to solve it. Moreover, decision-making in architectural design operates at different scales in rapid succession and is seldom linear. Designers often move back and forth between strategic and detailed decisions as a way of defining, and redefining, the means, goals, and criteria for evaluating the final design. In fact, a designer may be fairly far along before s/he finally decides which of the client's specifications to satisfy and how the client's goals relate to other aesthetic or cultural interests s/he might have. These complex normative and substantive decisions are difficult to model using computers, and in fact it may not be possible to completely automate design.

Instead, we have spent the past several years using computers to *aid* rather than automate design. We have developed a series of computational design aids that we call "case based design aids" (CBDAs). CBDAs provide human designers easy and flexible access to past experiences, and allows the humans to make the inferences and to choose how the information will be used in the design.

In this paper we briefly describe a CBDA called "Archie," then discuss three particular issues: 1) How can architectural case information be structured in a database? 2) How can a designer be provided general information in a CBDA while maintaining the advantages of using specific case information? 3) How can cases be indexed for use specifically within architectural design? In the following sections we describe Archie, explore questions of generalization and indexing that developing Archie has raised, and suggest some future directions for further research and development.

themselves over time and adapted themselves to different conditions. In a series of house designs, for instance, Frank Lloyd Wright modified basic models of human habitation to produce a wide range of variations which adapt themselves to specific environments while maintaining their essential organization or logic. Suppose we adopted an organic metaphor, conceiving of communications and

Background and Rationale

Archie is the result of an ongoing collaboration between the College of Computing and the College of Architecture. We are interested in exploring how to develop aiding systems for design, and particularly how access to cases can aid design. We are focusing on conceptual design; during this early stage of design decisions strongly influence the future course of the project and can be changed relatively easily. Whereas there are many kinds of decisions that are important during conceptual design, in Archie we have created a system to help designers understand different intentions for action of a range of stakeholders in a building project, such as users, owners, and builders, and how these intentions relate to design decisions about building form. Archie provides easy and flexible access to case study evaluations of buildings (in the present version, libraries and courthouses), that designers can adapt to their own needs. ARCHIE is intended to help experienced designers make initial conceptual design decisions and/or evaluate their own designs. It also helps novice architects and student users learn design principles, problems, related responses, and lessons.

Archie is based on an artificial intelligence (AI) paradigm called *case-based reasoning* (CBR) and a specific approach to *post-occupancy evaluation* (POE) case study evaluation of buildings. Case-based reasoning (Hammond K., 1989; Kolodner J. et al., 1985; Schank R., 1982) is a theory and technology within AI based on the idea that humans often solve problems by using specific past experiences. These experiences, or "cases," are used to explain new situations, are adapted to meet new demands, or are used to evaluate new solutions (Kolodner J, 1993). For instance, if a designer is faced with the problem of designing the information desk at a community library, s/he may remember similar cases s/he has experienced and adapt one or several of these to her current design. Case-based reasoning has been applied to a wide range of domains, such as scheduling (Mark W., 1989), diagnosis (Bareiss E., 1989; Koton P., 1988), planning (Hammond K, 1989), explanation (Kass A. & Leake D, 1988), design (Hinrichs T, 1992; Hinrichs T. & Kolodner J., 1991; Navinchandra D., 1991), and architectural design (Domeshek E. & Kolodner J., 1991; Domeshek E. & Kolodner J., 1992; Goel A., et al., 1991; Pearce M. et al., 1992). Effective case-based reasoning depends on having relevant cases in the system that can be applied to the problem at hand, and on retrieving a reasonable set of relevant cases quickly and easily.

In addition, Archie is based on post-occupancy evaluation (POE). POE is a set of techniques that assesses the effectiveness of buildings that are in use (Zimring C., 1987; Friedman A. et al., 1978; Preiser W. et al., 1987). Although it has been used to examine a wide range of technical and social issues, most POE work has focused on learning how successful a building is for various stakeholders, such as different types of building users, clients, or designers. Our approach to POE focuses on a specific set of design problems: how to resolve multiple intentions simultaneously. Any given design decision often must consider multiple considerations. For instance, in a community library, librarians need to be accessible to patrons, yet be able to get their work done without interruption. Depending on the exact context, a successful design must accommodate both of these intentions. In our POE work, we conduct field case studies of buildings to try to uncover these intentions through observation and interview.

The use of cases in design has multiple advantages. Human experts do not simply use systems of rules, they often access libraries of experiences (Riesbeck C. & Schank R., 1989). Cases are often vivid and specific and encourage the designer to consider how the case fits into the current problem. The effort to adapt cases encourages the designer to develop a mental model of the problem and solution. However, whereas specific cases may carry significant lessons, if the designer does not have a sufficient general framework for understanding them, s/he may not find them useful. In developing Archie, we have linked specific case descriptions of buildings with more general statements.

The structure of content in Archie

Archie is built using an experimental shell intended to ease construction of Case-Based Design Aids (CBDAs) called "Design-MUSE" (“Design Memory Utility for Significant Experiences”) (Domeshek E., 1993; Domeshek E., et al., 1992). Implemented in Common Lisp on the Macintosh, Design-MUSE provides a flexible shell for entering text and graphic information, indexing information, and creating hypertext links. CBDAs for other domains have also been built on top of this shell (Domeshek E, 1991).

The technical implementation of Archie is discussed in depth elsewhere and we will only review it briefly here (see Domeshek E & Kolodner J, 1991; Domeshek E, et al., 1992; Goel A. et al., 1991; Kolodner J, 1993). The essential part of our system is a library of cases that is intended to cover the set of problems for which the users may need help during conceptual design. Cases are composed of: “designs” (graphic or written descriptions of buildings); general problems; general responses; and stories describing how these operate in actual buildings. The stories include "successes," "failures" and "mixed outcomes," and are indexed for the user's domain.

The case library and the user interface, which in our case is provided by the Design MUSE shell, are the main parts of our system. Most windows are divided into several panes which provide some particular type of information. Concerning the content of cases, full advantage is taken of the facilities provided by the Design-MUSE shell, namely to fill and use the panes PROBLEMS, STORIES and RESPONSES from the LESSON window. At the same time, the system is enhanced by using the facilities offered by the DESIGN window of Design-MUSE. The following paragraphs describe the kind of information associated with each pane of the window and how this information is structured.

Problems

A problem is a general situation that a designer can encounter. It is written to illustrate conflicting intentions with an implementation which results in a troublesome outcome for some stakeholders. The components of a problem include:

The *context*, which provides information for indexing. In our system the context includes the following:

- General cross building concerns that may be applicable to all sorts of buildings such as economics, fluent circulation path, functional adjacency, HVAC, lighting, acoustics and anthropometric considerations;
- general usage concerns focusing on the nature of the building category, such as privacy, efficient construction, security and safety concerns that might be specific to public or private buildings;
- concerns that are specific to a certain building type (in our case, libraries and courthouses).

Intentions, that is, goals for action in the building that have significance for different stakeholders, and especially those which might result in conflict situations.

Impacts: prediction about or observation of outcomes, or implication of situations and the difficulties of trying to balance conflicting intentions.

Abstract and concise *graphic illustration*, which can vary from bubble diagrams to scaled details.

For example, our evaluations of libraries revealed the following problem that has significant influence on their layout:

> *Unrestricted access to the toilets from the reading rooms is required, but users may take advantage of the seclusion to tear out pages from books.*

Responses

A response is a general strategic approach to the solution of a given problematic situation. For designers, it usually provides information about the form of buildings. As we write a response in the Archie program, it provides important points about positive or negative condition(s) raised in the problematic situation. They also represent one kind of lesson a particular case can teach. It is a strategic choice a designer or organization might make.

A response should be general, but not too abstract, and should be suggestive rather than imposing a solution on the user. Furthermore, the general response should describe the outcome, which means the resulting state of the world when the solution was carried out. This outcome may need to record points of view of several different stakeholders. Consequently, some possible responses to the problem given above are:

In public buildings, allow an easy access to the restrooms from the outside or entrance hall, after the visitors/users have passed out through check out and control areas.

Place restrooms near: building entrance; supervised children's reading area, or other spaces where staff members are present.

Locate the entry to the restrooms where users must pass by the desk of a librarian or other staff members .

Stories

A story illustrates a specific example of a general problematic situation. It may also provide a specific example of a general response to a problem. A story consists of the following components:

A brief description of the existing design involving the entities mentioned in the general problematic situation.

Brief interviews of the users involved, verifying the evaluation component. They should mention if the users face any other problems connected with this situation and how it can be solved, and also any suggestions made by users.

Response to the problem indicating if the intentions were satisfied and that mention how and why.

Graphic illustrations to support the story.

Consider the following story that illustrates one implementation of the problem, and responses listed:

In Buckhead Public Library, the public restrooms are located adjacent to the public lobby near the circulation desk at the main entrance. Visitors can easily access the restrooms from the reading areas, but they must pass through the circulation area on the way. However, visitors complain that they have to walk all the way to the entrance.

Nonetheless this pathway makes it difficult for visitors to smuggle books into the restrooms without being noticed by staff members working at the circulation desk. The arrangement also allows unobtrusive supervision of the visitors without their being subjected to close scrutiny.

The library had been designed so that the public meeting rooms could be kept open after library hours, and the restrooms were accessible from outside the library itself. But now, the access is closed since the public meeting room is not kept open after the library hours. So the only access is from the circulation desk.

ARCHIE's current implementation on the Design-MUSE involves the retrieval of design "stories" via specific, previously identified architectural "problems" addressed by each of these stories. Each pair of problems and stories is accompanied by appropriate "responses" — how the architect dealt with the "problem" in relation to a particular "story." This format has many beneficial uses for an architect trying to solve a problem she is having with a design she is developing. However, this format does not address all of the needs of an architect who is formulating the design for a new building.

We conducted several small scale usability tests, in which we asked architecture students to use the system to evaluate existing plans of small libraries. Whereas students generally found the system interesting and engaging, almost all of them stated that the indexing was confusing and the indexing vocabulary was awkward. They also indicated that they needed more information while viewing the cases' problems and responses. This need was due to factors such as lack of sufficient architectural background, lack of detailed information about the specific case/problem at hand, and, at times, terminological confusion. Consequently, we are currently considering how to add "guidelines" to the system and how to refine the indexing.

Guidelines

The main purpose of guidelines in the Archie system will be to provide general information. This information will also help designers communicate with the system more effectively so that they are able to take full advantage of navigation among building descriptions, stories, problems, and responses.

As they are employed in architecture, guidelines include one or more of several components: (1) goals, such as "make circulation accessible to able-bodied and disabled users"; (2) rules of thumb or standards for implementation and evaluating implementations, such as "all corridors should be 36" clear"; (3) lists of stakeholders and their intentions, such as "disabled people would like to enter buildings in the same graceful way as able-bodied people"; (4) critical design features affecting the intentions, such as "it is critical that the path of disabled people is continuous; that is, it has no steps or barriers anywhere along the route..."

There are some points to be stressed. First, we did not intend to cover all related information (and in fact, it is almost impossible to do so). Rather, we hope to help designers understand a set of key issues and give them the background necessary to access the specific information in the system. Second, we believe that there is no single way of approaching the design process. Guidelines in our system should not be seen and used as rigid sets of sequential instructions but rather as loose frameworks. Moreover the guidelines are intended for a wide spectrum of users -- from non-architects to novice architects, from architectural students to experienced architects.

Below is an example of how guidelines may be organized in our system :

Circulation spaces

Entrance

Stakeholders and their activities: The entrance allows people to recognize the way into the building, and should be easily identifiable. Disabled persons, children and older people are frequent users of libraries. They do not like being labeled as different, and if possible the main entry should be easily accessible to everyone. Often people wait outside for the library to open or for a ride and, depending on the climate, need some kind of protection from the weather.

Lobby/entrance hall

Stakeholders and activities: The entrance hall normally accommodates the flow of the public through the space and various other facilities: people looking at the notice board, the building directory, display cases, public telephones. If the entrance hall also serves meeting and/or lecture rooms, etc., consideration must be given to the maximum number of people leaving these areas at any one time.

Several areas may have direct access from the entrance hall, for example, the circulation desk (which should be visible from entrance) and all public areas including vertical circulation which are not behind the control counter; also ancillary facilities such as exhibition space, meeting rooms, cloakroom, lavatories etc. If ancillary facilities are to be used outside library hours it must be possible to close off the library areas, preferably with one set of doors.

Rules of thumb: International Federation of Library Associations and Institutions (IFLA) recommends that 10-15 % of all public areas and 20-25 % of all staff areas should be allowed for circulation. These figures make provision not only for entrance hall, corridors and stairwells

but also for cloakrooms and lavatories; the higher figures are for large libraries with a high degree of division into separate rooms/ departments.

The guidelines can be used when the user initially enters the system, or at any time to help him/ her understand and/or clarify issues.

An example of using the system

The following is an example of how the system might be used: An experienced architect is looking into circulation concerns in a library which she is not familiar with. First s/he looks up the Guidelines about "Circulation" to get oriented, as seen in Figure 1.

S/he reads the Guidelines and notices that main entrance access and lobbies are a major concern in public buildings like libraries. As seen in Figure 2, s/he retrieves stories about "Accessibility" in "Public" buildings. By doing that, s/he can use some important keywords related to the Guideline which is provided by the system.

This retrieves stories about lobbies and entrances and general access to spaces from interface spaces. The architect notices that several of the retrieved stories mention noise as a major consideration when organizing the main access to buildings, so s/he decides to retrieve some stories specifically about acoustics.

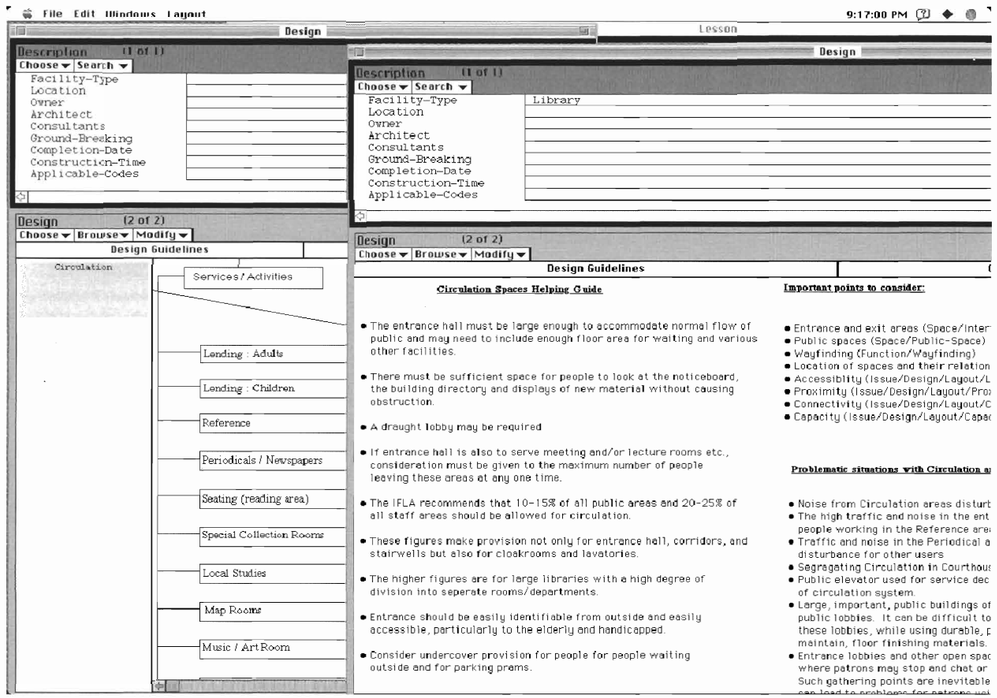


Figure 1: The user looks up "Circulation" guidelines to get oriented.

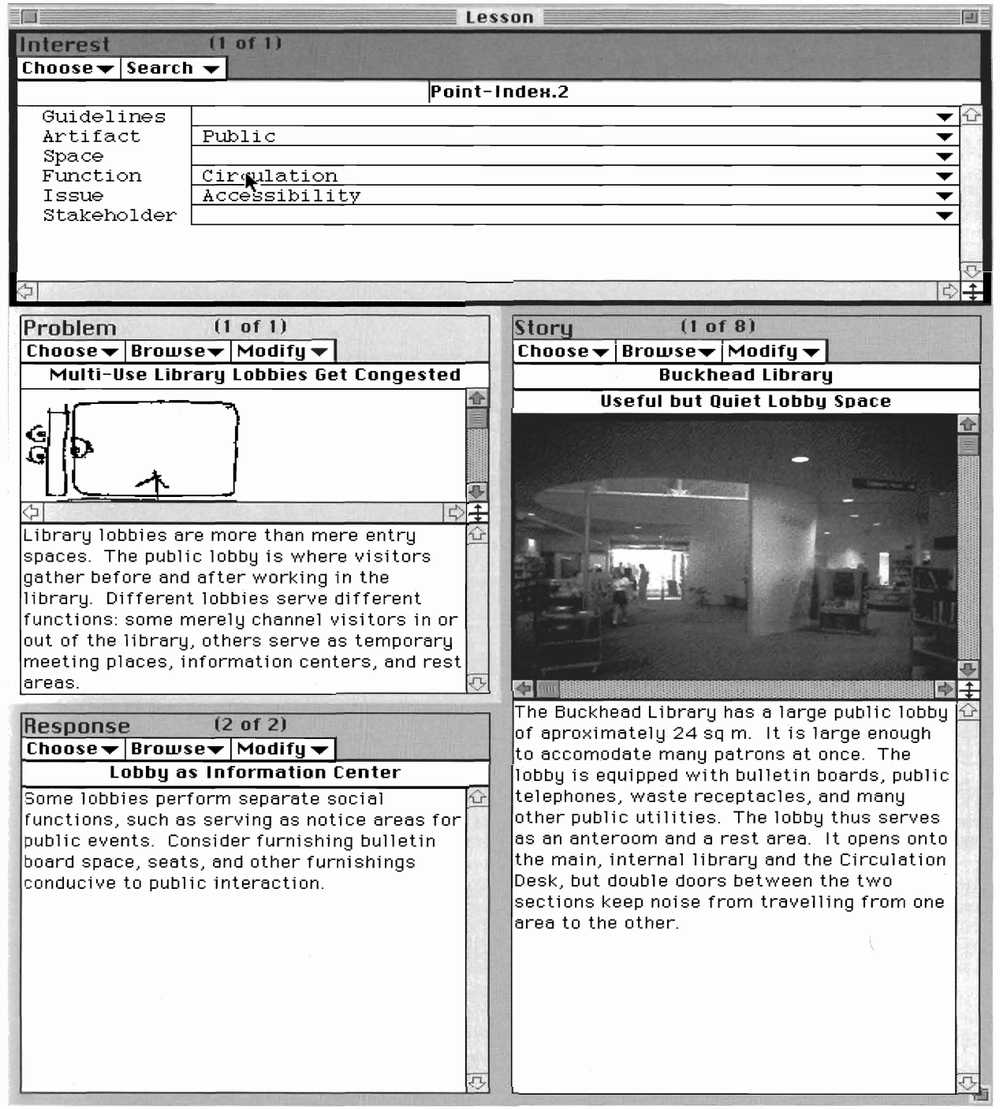
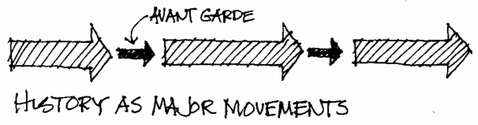


Figure 2: The user retrieves stories about "Accessibility" in "Public" buildings.



In *Theory of the Avant -Garde,*[10] Renato Poggioli points out that many authors view architectural history as movements, periods of consolidation, such as the Beaux Arts, Modern, or Post-modern, interrupted now and then by short bursts of avant-garde fervor and experimentation. Poggioli argues that we can just as easily look at history as long periods of avant garde activity, with relatively

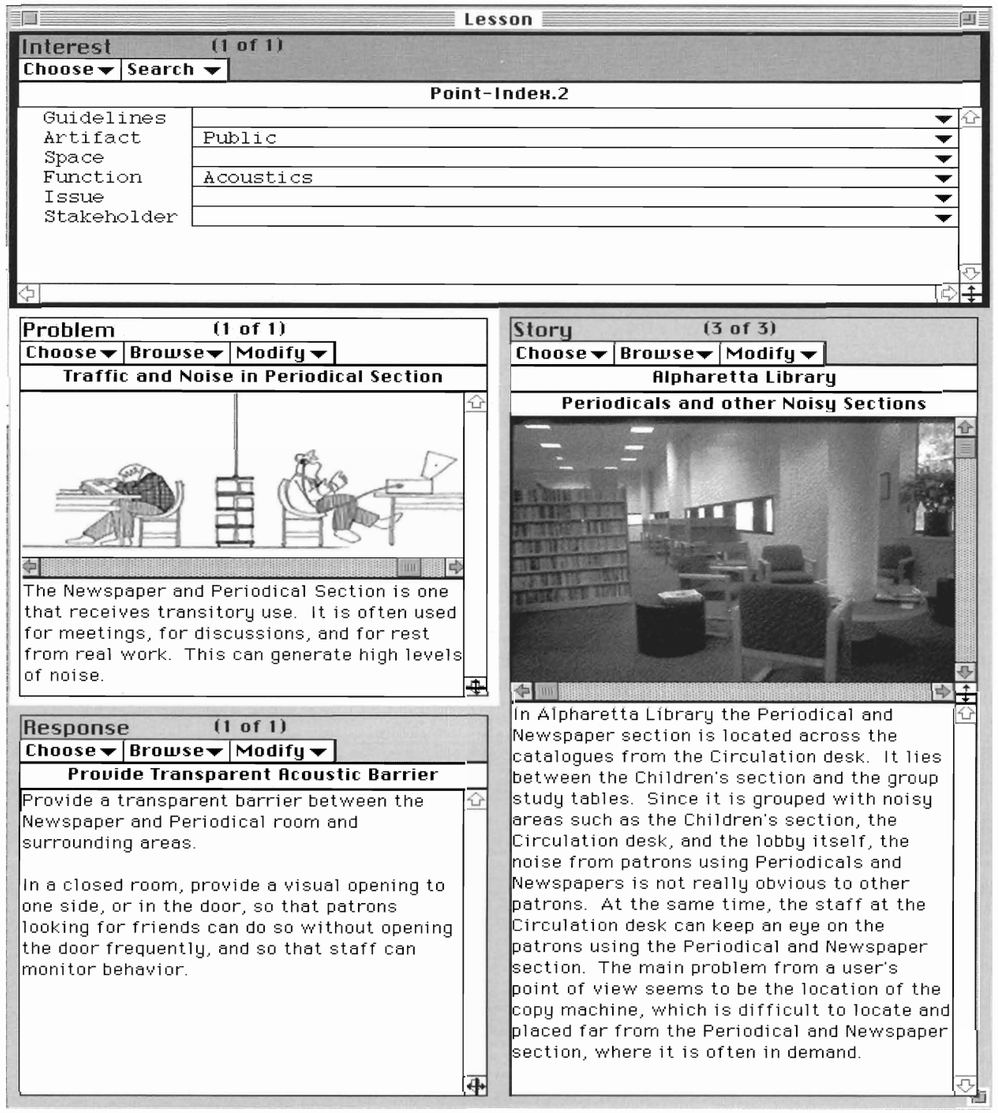
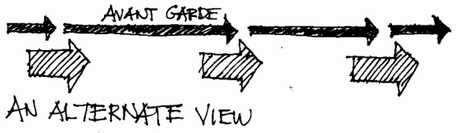


Figure 3: The user reads all related stories, associated problems and its responses about "Acoustics" in "Public" buildings.



After readings these stories, s/he wants to double check and see if there are any acoustical problems s/he has forgotten about. So, s/he retrieves the Guidelines for "Acoustics". (Figure 4) As seen in the example, the user has access to detailed information about a particular area throughout the interaction process. Even though some design principles are provided in the Response section, the Guideline section covers the whole investigated area regardless of a particular problem.

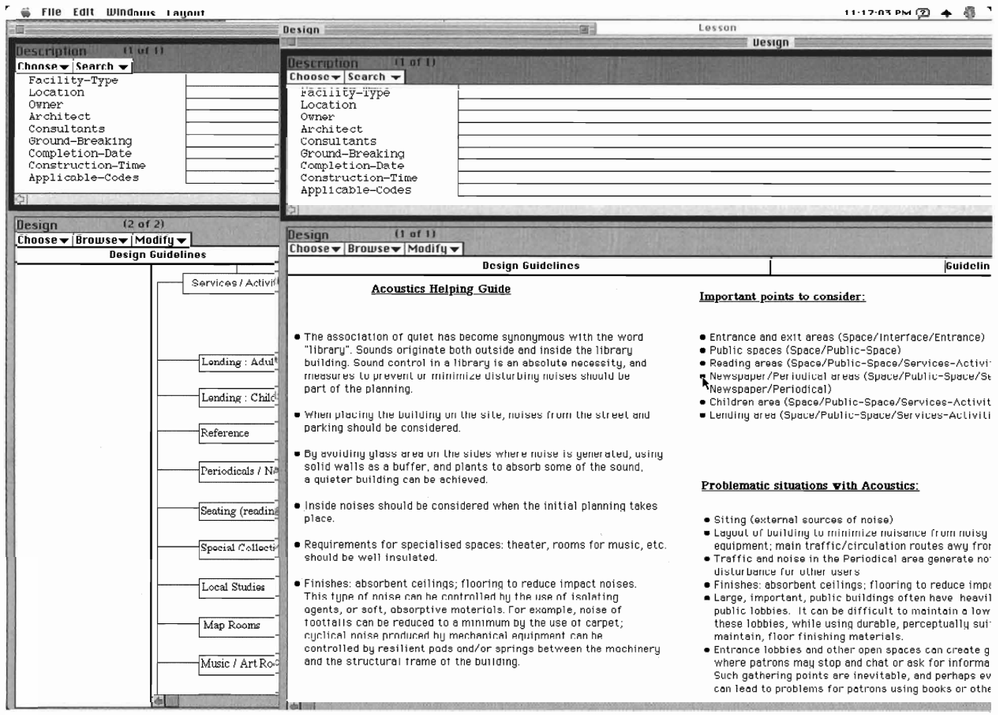


Figure 4: The user retrieves the Guidelines for acoustics.

For example, the following problem addresses circulation in libraries:

> *If the public lobby is very small, the visitors waiting for an event in a community room tend to gather inside the library, near the circulation desk, and produce noise that bothers other users.*

The responses for this problem are:

1. Provide a separate lobby for the community room.
2. Use stacks or other features to separate the reading areas from the noise of the lobby.

short periods of consolidation or agreement around a given architectural dogma or style. He asserts that the avant-garde, rather than the architectural movements, has provided the central impetus for the development of architecture. After a period of experimentation and rapid change, of great advarcements and interesting sidetracks, we appear to be entering a period of consolidation. We're seeing ourselves trying to regroup, to integrate, to bring

The guideline for circulation, however, covers more general principles. In this case, whenever the user gets confused or cannot proceed any further because of the lack of more detailed (or general) knowledge, at any stage, s/he can access those guidelines in order to learn more about the area.

Indexing

The most important issue in cased-based reasoning is retrieving appropriate cases (Kolodner J., 1993). The index of a single case determines how and when the case should be retrieved. The choice of indexes is very important because the indexes represent an interpretation of a situation, one that takes into account the way the user might think about a situation and the circumstances in which the user might want to recall the situation.

A first concern is what kind of stories are to be dealt with. This system focuses mainly on libraries, but the fact that a library shares many features with other public buildings challenges the indexing vocabulary to be easily scaled to cover other public buildings. In our system, cases about courthouses are indexed similarly with the library stories and show the inter-domain compatibility of the system.

Second, our initial usability testing showed some problems in specific use of indexes by architects. There was a general desire for a different format for accessing the case information. They preferred structures that use architecture's general functional/ spatial decomposition as a way of indexing the problems/responses/stories already in the system.

The existing ARCHIE uses descriptive indexing. The indexes are composed of descriptors specifying different design issues, such as structural component, functional system, stakeholder perspective, and lifecycle. Given information about a part of the design, the system searches for descriptions mentioning that part, and finds stories with either "positive" or "negative" outcomes that identify pitfalls and opportunities (Domeshek E, et al., 1992). However, the current indexing style does not have an architectural organization structure. Without having an architectural organization structure, the links between different categories as well as the search process may be confusing for architects.

To resolve this, we are refining the indexing structure as a five-level hierarchy. At the highest level is the core of architectural artifact; the next level is the type of architectural artifact divided into sub-fields (Residential, Non-Residential); at the third level is the type of sub-fields (Public, Commercial, etc.); at the fourth level are the main general spaces used in those sub-fields (Public Space, Interface spaces, Private spaces); and at the lowest level are specific kinds of activities (Lending, Reading, Reference, Seating, etc.). This hierarchy is presented in Figure 5. In addition to representing the structural relations between the five levels, this hierarchy classifies the "fixedness" of the architectural artifact: the spaces in the lowest level can be changed according to the domain (library, courthouse, office building, etc.), while the highest levels remain fixed respectively. For example, the requirements for Circulation of libraries and courthouses are different, while the requirements for Circulation of Public buildings always remain the same.

The main issue is to create an indexing vocabulary general enough to cover the range of tasks the case-based reasoner is responsible for and at the same time specific enough to make necessary differentiations among cases in order to retrieve only a small number of relevant stories for a query.

How the system addresses the needs of the users

The kinds of decisions that users make are related to their design goals and to the information that they need in order to accomplish their goals. A good indexing vocabulary should provide adequate items to handle users' decisions. Initially, our indexing vocabulary used just a functional approach. However, in order to address the users' needs the vocabulary was refined to also use a reminding approach Consider the Buckhead public library story presented earlier as an example of how the system addresses the design goals

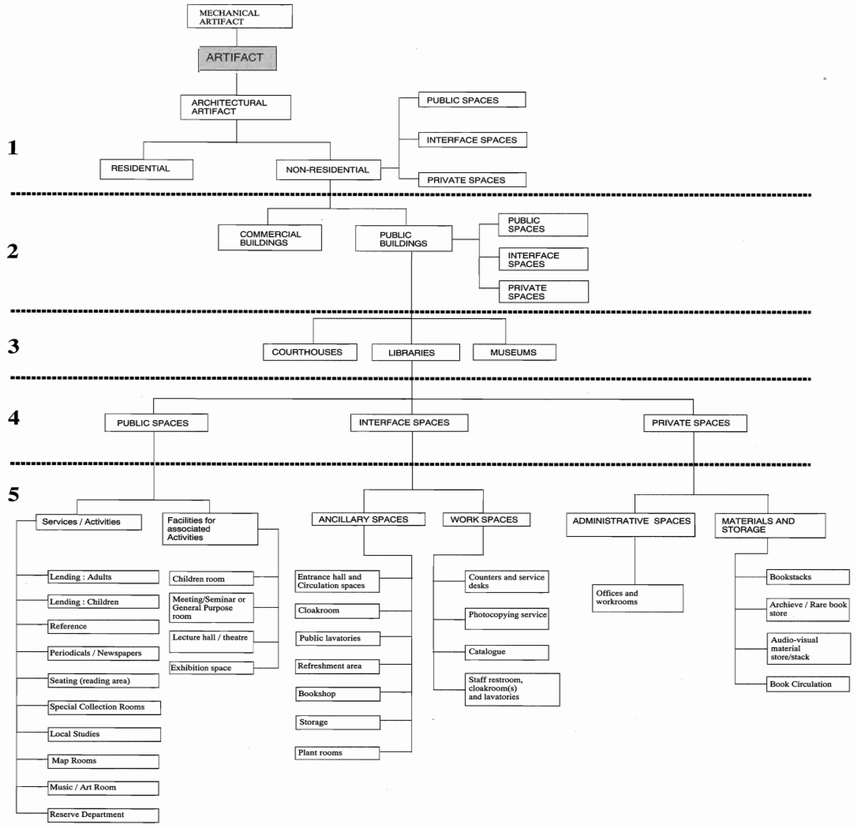


Figure 5: The index hierarchy.

of the users. Some design goals addressed by this particular story may be the following:

- designing the position of private spaces (including the restrooms)
- designing the position of the alarm system
- remodeling an old building with a new functionality

In order to evaluate these goals we need the following information:

- statistical information about the books damaged or stolen, in order to know how bad the situation is
- can the presence of storage spaces really improve the situation?

things together. To be effective as researchers, we need to be making some judgements about things that are more effective than others and ways in which we can share the benefits or discoveries of the many diverse programs that have evolved. While this consolidation is important, we need to be careful that it does not cut us off from continued exploration or what we can imagine is possible. If

Here is a check to see how the indexing vocabulary addresses the above users' design goals. The following is an example of indexing these goals in the system:

ARTIFACT/Non-Residential/Public/Library
SPACE/Interface-Spaces
SPACE/Interface-Spaces/Restrooms
FUNCTION/Circulation
FUNCTION/Security
STAKEHOLDER/Designer/Architect
STAKEHOLDER/User/LongTime Worker

However, the remodeling of spaces is not well addressed in the example above. This is not necessarily bad, because the indexing vocabulary does not need to cover everything. The answer to "What may happen if the space is remodeled?" can provide an appropriate indexing vocabulary to cover this aspect. It seems obvious that an improvement is sought. However, it is not obvious that improvements will fail if some fine points are ignored. This aspect of failure may be indexed as:

ISSUE/Efficiency or Maintainability

However, the case is about "non-efficiency", and, therefore, if a user cannot find a particular feature indexed, s/he should try to find an opposite feature as an index and consider only the retrieved failure stories.

Conclusion

Constructing the system to be used by novice and experienced users eliminated many of the problems associated with trying to anticipate the expertise of the user. The straightforward approach of the Lesson Window in Design-MUSE gives a clear outline of the information presented so the user cannot get easily lost if they are at least familiar with the Macintosh window format.

The vocabulary, presented as menus, eliminates the problem of users trying to find appropriate terms to retrieve information, although, in general, the user is assumed to be an architect or at least to be familiar enough with the architectural jargon. Further, the implementation of the Guideline dimension provides assistance for filling in a user's knowledge gaps concerning general architectural terms and issues for the novice user and concerning the terms for the Library artifact for an experienced architect out of her domain of expertise.

The functional/spatial breakdown of the indexing vocabulary to represent the stored cases was done specifically with the designer/architect in mind. Spatial entities and functions are the entities that an architect thinks about and addresses when designing. We followed this approach in reorganizing the system: the case presentation first addresses the spatial entities and functions addressed by the particular story. Concluding each story with "user recommendations or comments" is also very "designer logical" as a designer's goal is to satisfy and please the user as much as possible.

In building the initial case library, our approach tries to provide coverage of the common problems encountered in the design of libraries. In the testing and training phase, the inadequacies present in the case library, in the content of cases, and in the indexing scheme should be fixed. It is hard to tell at this point, without significant usability testing, exactly what all of these inadequacies are. However, we discovered up front that, because each story addresses so many issues in a design or could help in so many different design situations, many of the indexes for stories are similar. This often leads to the retrieval of large numbers of stories that the designer has to wade through. In order to retrieve a limited number of the stored stories, using the current search option, "Matching Any of the Interests" choice should be avoided, while using, "Matching Most of the Interests" seems to work well. Along this same line, the more specific the user is up front about his/her area of interest the better. If no suitable stories are found, one can make retrieval specifications gradually less specific to enlarge the number of stories or problems s/he retrieves to browse.

ARCHIE currently exists as a set of 200 analyzed stories, 82 problems, and 148 responses, plus building descriptions, derived from evaluations of six libraries and two courthouses. We are refining the indexing to provide user support for a broad set of stories and problems. We are adding more stories to more generously fill out the indexing hierarchy. The most significant addition that should be made to this system to make it more useful is the inclusion of complete architectural drawings, corresponding to each story, that could be brought up in the Design window when a story is retrieved. This visual information is crucial if this system is to provide significant help to a architectural designer. Designers are graphics-oriented. Shown below is a sample run from current ARCHIE (Figure 6).

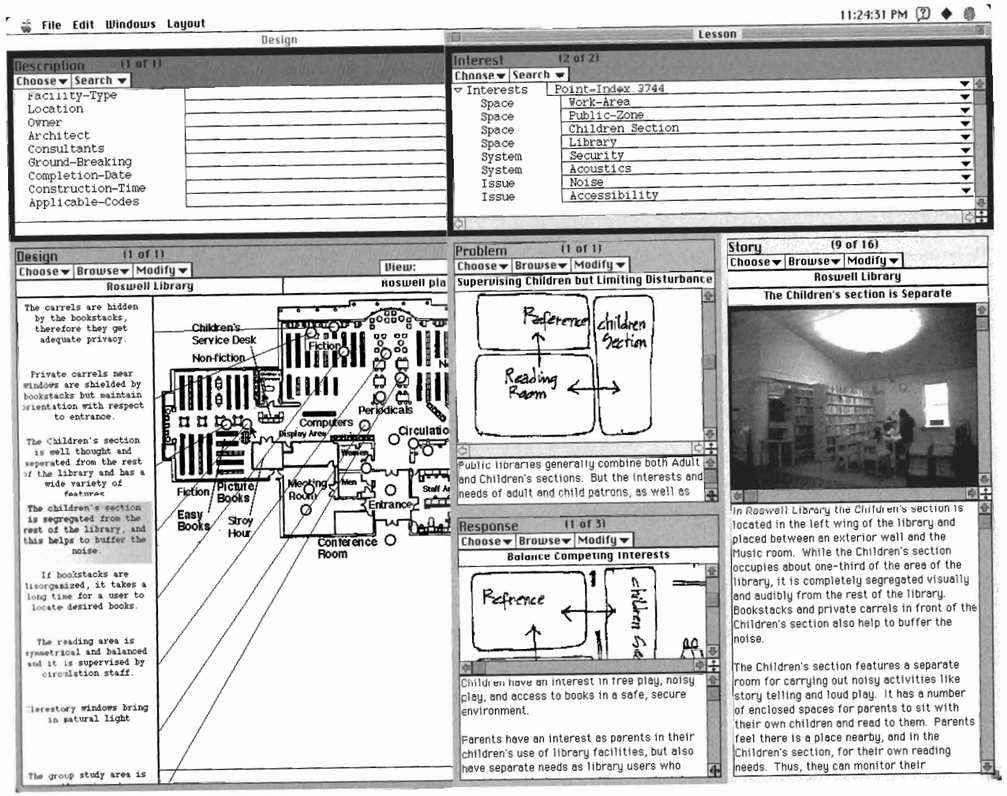


Figure 6: Sample run of ARCHIE in its current state.

we cease to wonder what might be, there will cease to be anything new. We need to provide a context for continuity *and* change, for communication *and* invention.

As a general case-based reasoning tool, this application of Design-MUSE takes advantage of one of the most significant offerings of CBR: extended, non-volatile memory. As a reminding or educating device, the system's ability to store and retrieve far more information than any architect, experienced or novice, can remember is its key attribute. Our goal is to support the creative development of an architectural design idea.

We are currently initiating a program of testing Archie with architecture students at various levels, from beginning to advanced. We are also revising the interface to make the system more intuitive to use, and are adding new material to the system.

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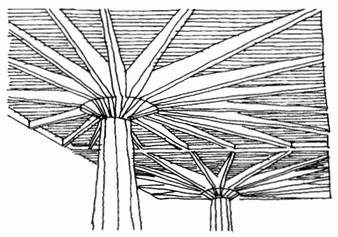

"Invention can only be done deliberately if the inventor can discern similarities between the particular result which he is envisaging and some other actual result which he has seen and stored in his memory. ... An inventor's power to invent depends on his ability to see analogies between results and, secondarily, on his ability to see them between devices..." David Pye[11]